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ABSTRACT

Although the use of animated visuals is both common and popular among computer based instruction (CBI) designers, the theoretical and empirical foundation for their use have not been firmly established. Animated visuals represent a subset of instructional visuals, not a distinctive set. For this reason, general conclusions from research on static visuals are thought to extend to animated visuals. However, the extent to which animated visuals represent elaborations or departures from this research is questioned. The purpose of this paper is to review current empirical evidence of the instructional effectiveness of animated visuals as an adjunct or alternate presentation strategy. Current applications of computer animation in instruction are discussed and a taxonomy to aid in prescriptive and evaluative purposes is suggested. The theoretical foundations of animated visuals in the areas of perception and long-term memory are also discussed and a brief summary of static visuals research is presented. Finally, conclusions and prescriptions resulting from this review are presented. A summary of the empirical research studying the instructional effects of animation is presented in tabular form and three figures depict examples of different instructional uses of animation. (75 references) (Author/CGD)

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A Review of Animation Research in Computer-Based Instruction

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A Review of Animation Research in Computer-Based Instruction

Abstract

Although the use of animated visuals is both common and popular among CBI designers, the theoretical and empirical foundations for their use have not been firmly established. Animated visuals represent a subset of instructional visuals, not a distinctive set. For this reason, general conclusions from research on static visuals are thought to extend to animated visuals. However, the extent to which animated visuals represent elaborations or departures from this research is questioned. The purpose of this paper is to review current empirical evidence of the instructional effectiveness of animated visuals as an adjunct or alternate presentation strategy. Current applications of computer animation in instruction are discussed and a taxonomy to aid in prescriptive and evaluative purposes is suggested. The theoretical foundations of animated visuals in the areas of perception and long-term memory are also discussed and a brief summary of static visuals research is presented. Finally, conclusions and prescriptions resulting from this review are presented.

Introduction

Animation is an increasingly popular element in computer-based instruction (CBI) and its use, along with other types of graphics, is often advocated (Bork, 1981; Caldwell, 1980). Even a casual review of the many commercial educational software packages available today demonstrates the popularity of animation among software designers. Unfortunately, animation is often incorporated into a program with the intent to impress rather than instruct the user. Sound and graphics have always been among the most seductive educational aspects of computer technology. Increased hardware capabilities coupled with increasingly literate and sophisticated educational consumers demanding "leading edge" design has the tendency to spur greater amounts of "glitter" in software without serious regard to its instructional effectiveness. Hence, the "glitter" of the technology is often accepted as a substitute to proven worth.

There appears to be two fundamental approaches to designing and evaluating computer-based instruction (CBI) — technocentric design and instructional design. Technocentric design is hardware-centered and is evaluated based on how well the capabilities of the hardware are utilized, whereas instructional design is learner-centered and tries to incorporate sound instructional strategies. It is the major contention of this paper that the design and evaluation of animated visuals should follow an instructional design perspective. Unfortunately, many educators continue to evaluate the effectiveness of animation based on technocentric design principles. This may be because the majority of educators are still functioning at the "familiarization" level of computer technology (Rieber & Welliver, in press) in that they are easily impressed by features of the technology which experts take for granted.

Although inappropriate instructional applications of animation are frequently caused by technocentric attitudes, little guidance has been provided to designers and consumers by researchers and reviewers. Although much research has been done to establish the contexts where static visuals are potentially effective (Dwyer, 1978, for example), little research has been conducted to investigate instructional uses of animation directly or to systematically study what potential differences between static and animated visuals exist. Additionally, the empirical data presently available regarding animated instruction has been inconsistent. A premise of this paper is that animated (or dynamic) visuals represent a subset of instructional visuals, not a distinctive set. Hence, it is expected that guidelines generated from the large body of research on static visuals extend to animated visuals, but do not necessarily fully account for differential effects, if any.

It is suggested that CBI applications of animation serve one or more of the following six functions: 1) Cosmetic; 2) Attention-gaining; 3) Motivation/Reinforcement; 4) Conceptualization; 5) Presentation; and 6) Interactive dynamics. These six functions represent an initial attempt at establishing a taxonomy of the uses of animated visuals in instruction. It should be noted at the onset

that this is ***not*** meant to be a media comparison review. The conclusions and prescriptions are directed toward animation, a media attribute, and not toward the computer medium directly, although the contention is made that few other media possess the inherent capabilities to deliver animated instruction across the taxonomy as does the computer. This is consistent with the contentions and arguments presented by Clark (1983) and others (Solomon & Clark, 1977; Solomon & Gardner, 1986) that instructional design, not media, accounts for differentiated learning effects. This discussion is but a first step in determining if animation represents a sufficient (though perhaps not necessary) condition for learning when the learning task is congruent to the attributes of animation.

The purpose of this paper is to review current research investigating the effectiveness of animation as a presentation (adjunct or alternate) strategy. Preceding this review will be a description of the taxonomy. Also, the theoretical framework underlying the potential effects of animation, specifically in the areas of perception and long-term memory retention and retrieval, will be briefly discussed. Additionally, the research and subsequent conclusions of static visual research will be reviewed. Since these related research areas are based on the same theoretical framework, they present a reasonable empirical substitute from which to draw tentative guidelines in the design of animated instruction.

A Taxonomy of Animated Visuals in CBI

In a recent review of instructional pictures, Levie (1987) suggested that motivation and learning are the primary motives to incorporating instructional visuals. In order to help CBI designers integrate animation effectively, more detailed elaborations of these motives are needed. For this reason a six category taxonomy is presented to help classify the uses of animation in CBI: 1) Cosmetic; 2) Attention-gaining; 3) Motivation/Reinforcement; 4) Conceptualization; 5) Presentation; and 6) Interactive dynamics. This taxonomy serves to clarify the instructional (prescriptive and evaluative) purposes of animation. It is possible, and likely, that the instructional intent and result of any one animated visual could be classified across more than one category. It is also very likely that the instructional intent can be entirely different from the instructional result when designers make decisions to include animated visuals based on misinformation, misinterpreted information, or no information.

Cosmetic

This is the only category which has no direct instructional intent. The purpose of animation is merely to make the program more attractive. Examples include special effects during opening titles or screens and are often used to advertise the product's or publisher's name. It is possible for cosmetic uses of animation to also perform an attention-gaining function by presenting an interesting graphic in-between lesson parts to pique attention. However, there are several dangers to using animation for only cosmetic reasons. The learner may not perceive the animation as merely adding to the "decor" of the program, but may perceive it as there for an instructional purpose. This not only detracts the learner's attention for an irrelevant task, but also risks frustrating the student when no instructional link is found, or worse misleads the student in some way. Issues in cosmetic uses of computer graphics appear similar to both static and animated graphics.

Attention-gaining

Just as with static graphics, attention-gaining is an obvious, practical, and rationale use of animation. Attention-gaining is an important initial event of instruction (Gagné, 1985). Animation can be an effective way of arousing and maintaining a learner's attention during CBI. Examples include interesting special effects for transitions between instructional frames or lesson parts. Special screen washes, moving symbols or characters (cartoon or text), animated prompts, such as arrows which direct attention to key words, paragraphs, graphics, or other screen items are still other examples of animated attention-gaining devices. Animated figures offer contrast to a static background, thus bringing the animated figure to prominence, thus amplifying or emphasizing important lesson information (Hannafin & Peck, 1988).

Motivation/Reinforcement

Motivational applications of animation have been used extensively, although perhaps haphazardly, in CBI design. In this context, animation acts as reinforcement or feedback to student responses. Much of the motivating appeal of animated visuals is due to novelty. Unfortunately, novelty effects, though real, are temporary and gradually disappear over time (Clark, 1983). Application of static or animated visuals to reinforce student answers must be made cautiously. Attractive and interesting graphics which occur when a student answers incorrectly may actually reinforce wrong responses. For example, an instructional program on weights and measures available from the Minnesota Educational Computer Corporation (MECC) illustrates, through animation, a gallon pitcher filling a number of quart pitchers. If the student responds that three quarts equal one gallon, then the final quart is spilled onto the floor. If watching milk being spilled onto the floor is more interesting to the student, then only an incorrect response will elicit this reinforcement. The power of computer graphics as a long-term motivational tool designed to increase student perserverance does not have much empirical support (Surber & Leeder, 1988).

Presentation

Using animated graphics as an adjunct or alternate presentation strategy represents the most direct instructional application of animation. This area represents the main body of reported research discussed later. Animation is used in two principal ways. First, it provides an alternative or supplement to text in defining a concept, rule, or procedure. Second, it provides an alternative or supplement to text in providing examples, nonexamples, or elaborations of a concept, rule, or procedure. The apparent processing partnership between appropriate use of visual (eg. static or animated graphics) and verbal (textual) information is the foundation of several theories of long-term memory (Bower, 1972; Paivio, 1979) and is discussed in more detail later. Reed (1985) described this use of animated graphics as a "learning-by-viewing approach" (p. 297-298). An example of this instructional application of animation is depicted in Figure 1. Static or animated graphics used in this manner can be classified as representational, analogical, or arbitrary (Alesandrini, 1984). Representational graphics are those that share a physical resemblance with the thing or concept that the picture stands for. Analogical graphics represent a concept or topic by showing something else and implying a similarity and the learner must be able to recognize the analogy. Arbitrary graphics do not look like the things they represent, but are related in logical ways. Arbitrary pictures include graphs, flowcharts, maps, and tree diagrams. Most of the empirical evidence discussed later involves representational animated graphics.

Insert Figure 1 About Here

Conceptualization

This category defines an application of animation which is closely related to presentation. Here, animation is used to aid a student's conceptual understanding ***without*** providing any new information to the student. This application does not replace or supplement definitions, examples, and/or nonexamples of concepts, rules, or procedures, but rather clarifies relationships through visual means. A good of example of this is the software program, ***The Factory*** (Kosel & Fish, 1983), which is represented in Figure 2. In it students attempt to create or replicate a product. The product starts out in raw material form as a square wafer. The raw material is sent through any number of combinations of punch, stripe, and rotation "machines" which successively alter the product into its final shape. By animating the product through the factory, students see the factory assembly process executed as they designed it. The program's animation does not contribute to the student's knowledge base, but rather provides a concrete representation of the process which involves a potentially complex array of relationships among individual components.

Insert Figure 2 About Here

Animation has a indirect relationship to the learning task when applied in this way. Its effect is very dependent on the learner's prior knowledge of the learning task. Novices, who probably would have difficulty in seeing abstract relationships on their own, would be expected to benefit from animation when used in this context.

Interactive Dynamics

Interactive dynamics represent an instructional application of animation where the role of animation is vital, but difficult to distinguish. In this context, computer animation permits the design of interactive programs in which students learn by discovery and informal hypothesis-testing. The graphics change continuously over time depending on student input, thus acting as a form of instantaneous graphic feedback. This application of animation is what Brown (1983) called "learning-by-doing". Successful examples include simulations, such as piloting an airplane or interacting with a Newtonian particle in a gravity-free/frictionless environment as shown in Figure 3 (diSessa, 1982; White, 1984), and learning musical concepts (Lamb, 1982). Other examples include graphic programming procedures in LOGO where students drive an animated "turtle" on the screen (Papert, 1980). However, it is important that students be able to perceive differences in the graphic feedback, an ability which novices especially have a difficult time attaining (Brown, 1983; Cohen, 1988; White, 1984). Several have indicated the need to structure the interactive dynamic in various ways to offset this deficiency (White, 1984; Rieber, 1988) or to augment such interactions with coaching or other prompts (Reed, 1985). Interactive dynamics represent a use of animation not easily replicated given media other than the computer.

Insert Figure 3 About Here

A Theoretical Framework

Several theoretical frameworks exist to support the contention that animation should be effective. This section describes two theoretical perspectives. First, several perceptual factors are briefly described which help to explain how the illusion of animation is made possible. Second, and more importantly, are current views on how visuals contribute to long-term retention of learned information.

Perceptual Factors

Perception is the process which involves selectively attending to and scanning a given stimulus, interpreting significant details or cues, and finally perceiving some general meaning (Levie, 1987). Visual cognition is the process of how people perceive and remember visual information (Pinker, 1984). Having students perceive meaning from animated visuals relies on tricking them to see something that really is not there. Certain basic perceptual factors help to explain this phenomenon.

Computer animation can be defined as a series of rapidly changing computer screen displays that present the illusion of movement (A. Caraballo, 1985). Animation, whether on computer, film, or otherwise, is not ***real*** motion, but only a representation of motion. Even the most sophisticated computer graphics systems operate on a "draw, erase, change position, draw" repetition to produce

animation. When individual, non-moving images are shown collectively at around 16 frames per second, the motion is ***perceived*** as smooth and continous. This is known as ***stroboscopic motion***. When images are shown at a rate of less than 16 frames per second, the motion appears choppy or jumpy. Even the most inexpensive computer systems available today easily match this perceptual requirement for adequate illusions of movement. (Interestingly, a commercially available electronic child's toy called "The Animator" operates at far less than the 16 frames per second level, but seems to readily elicit the movement illusion in children.)

Related to stroboscopic motion, is the ***phi phenomenon***, which is the illusion produced when stationary lights are turned on and off in such a manner that a moving image appears. Examples of this phenomenon include theater marquee lights, Las Vegas casino lights, and scoreboards in sports arenas. The phi phenomenon also accounts for animation produced by the coordination of computer graphic pixels.

Both stroboscopic motion and the phi phenomenon seem to occur because of the Gestalt law of continuity (Rathus, 1987). We tend to perceive a series of points as having unity, and so a series of lights is perceived as a moving object. Motion perception is a part of each individual's schema, or organized network of world knowledge (Norman, 1982), because we live in a dynamic world where very little visual information is truly static (Goldstein, Chance, Hoisington, & Buescher, 1982). Therefore, instruction can easily prompt an individual to ***expect*** motion. Consequently, through top-down mental processing, the individual then "sees" motion in a collection of carefully coordinated ***static*** lights in order to fulfill the expectation.

Long-term memory structures

Humans appear to be particularly adept visual learners (Kobayashi, 1986). The predominant theoretical explanation for this is the dual-coding theory advanced primarily by Paivio (1979, 1986). This theory suggests that there are independent encoding mechanisms, one visual and one verbal. Although competing hypotheses exist, such as those suggesting that all information (visual and verbal) is stored in propositional forms (Pylyshyn, 1981), the dual-coding theory has considerable empirical support. Although we may never fully know the physiological mechanism for visual memory storage, the dual-coding hypothesis probably presents the most useful ***model*** for describing and prescribing visual effects common in instruction (Anderson, 1978).

Paivio's (1979, 1986) dual-coding theory contends that pictures and words activate independent imaginal and verbal codes. Based on this theory, the superiority of pictures over words rests on several key assumptions. The first assumption is that separate coding mechanisms have additive effects, that is, if something is coded in both picture and verbal forms, it is more likely to be remembered than if only coded in one form (Kobayashi, 1986). The second assumption is that the availability of these two coding mechanisms differ in that a picture is more likely to be coded verbally and pictorially than words (Hannafin, 1983). Pictures are often remembered better than words because they are more likely to be encoded redundantly than words. Thus, better recall can be expected due to the availability of two mental representations instead of just one. If one memory trace is lost (whether visual or verbal), the other is still available.

Dual-coding is more likely to occur when the content is highly imageable. Paivio and Csapo (1973) investigated the relative contributions of imaginal and verbal memory codes. Their results indicated that higher recall was produced for pictures than for words under all conditions except when subjects imaged to words. Most of the supportive research shows that words, sentences, and paragraphs that are highly imageable are recalled better than those which are not highly imageable. The learning of concrete concepts precedes the learning of abstract concepts; concrete concepts are stored as images whereas abstract concepts are stored as verbal representations.

Animation, like any graphic, should be expected to aid the recall of verbal information when it serves to precisely illustrate a highly imageable fact, concept, or principle. Predicting learning differences based on using animated graphics ***versus*** static graphics is not as clear. Animated graphics should provide greater elaboration than static graphics when lesson information involves highly imageable facts, concepts, or principles that change over time. Hence, animation's attributes of motion and trajectory are distinguishable from the attributes available from static visuals in aiding mental storage and retrieval (Klein, 1987) in certain contexts. Physics instruction, such as that

involving Newtonian mechanics, is a good example of highly imageable lesson content that can be facilitated by graphics displayed over a time continuum. The presentation of animated examples demonstrating a ball being thrown can be stored visually as a concrete example. The rules that govern these forces as well as the application of these rules can then be stored in verbal representations. The animated examples allow a more precise image to be stored as compared to a static graphic using arrows and dotted lines representing the concepts of movement and trajectory.

Static Visuals and Learning

Different reviews of representational pictures in instruction report conflicting conclusions (Alesandrini, 1984; Levie & Lentz, 1982; Pressley, 1977; Samuels, 1970). Researchers studying the effects of pictures in prose learning prior to 1970 concluded that pictures generally did not aid in children's prose learning, and occasionally distracted from the printed text (Braun, 1969; Samuels, 1967, 1970). The distracting effect of pictures was explained by the principle of least effort (Underwood, 1963). According to this principle, when two stimuli are presented, the one which can more easily elicit the correct response is attended. Willows (1978) reported a more recent example of the distracting effect of pictures. Younger, less skilled readers were found to be more suspectible to this interference effect. This research seems to indicate that a fine line often exists between the learning and distracting effects of visuals.

Research conducted since 1970, however, points to the positive effect of pictures in prose learning suggesting that pictures can exert strong positive influences on learning given certain conditions. For example, evidence suggests that children's dependence on pictures decreases with age. As children grow older they become better able to produce their own internal images (Guttmann, Levin, & Pressley, 1977; Pressley, 1977). This evidence suggests the developmental importance of imagery ability. Imagery, like many other cognitive processes, develops over time (Lesgold, Levin, Shimron, & Guttman, 1975; Shimron, 1975). Related research has demonstrated the usefulness of teaching imagery strategies to older children as a learning aid (Lesgold, McCormick, & Golinkoff, 1975; Pressley, 1976).

A review by Levin and Lesgold (1978) reviewed "abundant empirical evidence to document the positive value of pictures" (p. 233). The most important conclusion of their review is that pictures should be highly related or congruent to the textual material; unrelated pictures or too complex pictures are superfluous and may be distracting. Others have offered similar design guidelines based on the conditions under which visuals exert positive effects (see for example, the "ten commands of picture facilitation" offered by Levin, Anglin, & Carney, 1987).

Dwyer (1978) reviewed over 100 studies investigating the use of supplemental pictures as an adjunct learning aid in expository text. The studies investigated the effects of realistic pictures that varied in the amount of detail from highly detailed color photos to simple line drawings. The results suggest that pictures facilitate learning for adults under certain conditions. Sufficient processing time is necessary when using visuals with realistic details. Richly detailed visuals require the learner to attend to and systematically scan the visual in search of essential learning cues. If insufficient time is given, students may actually choose to ignore the visuals and attend to the more familiar, printed text. Therefore, when lessons are externally paced, the most effective visuals contain relatively small amounts of visual detail.

The apparent contradictions concerning the effectiveness of pictures in reading require cautious interpretation. One explanation for why picture superiority effects were largely found ***after*** 1970 is that the facilitating conditions had been made more clear. Pictures effects, like most other instructional aids, do not generalize to all instructional situations. It is clear that there are contexts where pictures do not facilitate learning due to distraction effects and/or the inability of some readers to shift attention from pictures to text. However, ample contexts exist where pictures appear very useful in facilitating reading achievement. Dominant conclusions drawn from this research are: 1) pictures are superior over words for memory tasks; 2) adding pictures (external or internal) to prose learning facilitates learning assuming that the pictures are congruent to the learning task; 3) children up to about the age of 9 or 10 rely more heavily on externally provided pictures than older children; and 4) children do not automatically or spontaneously form mental images when reading.

Review of Animation Research

Given the rather ubiquitous presence of animation in educational software, surprisingly few studies have been reported. A variety of non-experimental work has been reported with animation. For example, Margaret Withrow, Project Director of the Research Department of Galludet College, has reported encouraging results using computer animation during language activities for hearing impaired students (Withrow, 1978; 1979). Other uses of computer animation include work in motion perception research (Proffitt & Kaiser, 1986) and testing (Hale, Oakey, Shaw, & Burns, 1985). Empirical studies, though rare, have been reported. The purpose of this section is to briefly summarize research on the effects of computer animation as an adjunct or alternate presentation strategy on learning. Table 1 provides a summary of this review.

Insert Table 1 About Here

One early attempt to investigate systematically the instructional effects of computer graphics was reported by Rigney and Lutz (1975). Forty undergraduate college students participated in a study on the workings of a battery. The study measured learning and attitudinal outcomes. Significant differences were found between groups receiving a verbal presentation versus a pictorial presentation which included animation. Higher scores were reported for the pictorial presentation group on recall tests of knowledge, comprehension, and application. This group also rated the lesson as more attractive. However, the study failed to discriminate between the effects of still graphics and animation. For this reason, it was not possible to attribute the learning gains solely to the use of animation.

King (1975) compared three presentation modes: 1) no graphic (text only); 2) text plus the use of still visuals; and 3) text plus animated visuals. Forty-five Naval training students participated in this study which taught the mathematical concept of the sine-ratio. No significant differences were reported between the three groups. Since the subjects were older and probably had already refined many personal learning strategies their dependence on external imagery was probably nominal. Other problems cited by King were the following: 1) the learning task was not sufficiently difficult (i.e. ceiling effects); 2) the criterial measures were heavily weighted verbally; and 3) the crudeness of the text and graphics displays by the host computer. The use of older subjects is a crucial and perhaps confounding variable for most of the computer animation studies.

Collins, Adams, and Pew (1978) studied an animated application of the SCHOLAR computer-assisted instruction system. Three lesson versions utilizing map features in the teaching of South American geography were compared: 1) interactive map; 2) static labeled map; and 3) an unlabeled map. The interactive map condition consisted of a computer graphic map of South America with blinking dots marking cities. During the tutorial lesson, an interaction between the student and map display was established. Student answers were reinforced appropriately verbally and graphically (with blinking dots). The static labeled map condition used SCHOLAR on a nongraphic terminal, but the student could look at a labeled map. The unlabeled condition was identicial to the previous condition except that the student was given an unlabeled map. The study was conducted in two parts: first with a group of nine high-school students, then replicated with a group of nine university students. Results indicated that the interactive map condition was superior to the labeled map condition, which in turn was superior to the unlabeled map condition. This study indicated differentiated effects of animated over static visuals. However, the instructional intent of the animation appeared to be as an interactive dynamic rather than as an adjunct presentation strategy. The animation was triggered according to on-task student performance. The surprisingly low number of subjects per treatment also warrants cautious interpretation.

Moore, Nawrocki and Simutis (1979) studied the following three presentation modes: 1) text

plus schematic representations; 2) text plus line drawings; and 3) text plus animated line drawings. Ninety enlisted military personnel participated in this lesson which involved the psychophysiology of audition. The subjects were tested for retention of facts, terminology, identification, and principles. No significant differences between the three presentation modes were reported. Again, however, methodological anomalies likely weakened the ability to detect differences. Subjects in all treatments were required to answer review questions after each of the four lesson parts: if they could not answer 85% of the questions correctly, they were forced back through the section until attaining the 85% criterion. For this reason, subjects probably reached ceiling levels before taking the posttest. Since only the posttest scores were used in the data analysis, it seems likely that potential lesson variation influences were masked.

J. Caraballo (1985) studied the use of animation using the following four treatment variations: 1) no instruction (used as a control); 2) text only; 3) text plus still visuals; and 4) text plus still and animated visuals. Eighty college seniors and graduate students participated in this study which taught the parts and internal processes of the human heart. Once again, no differences were reported between the text only and the other groups using visuals. The age of the subjects is again cited as a possible source of confounding. Additionally, the lesson locations where the visuals were placed were not systematically derived. It is not possible to determine if the embedded visuals were even needed to support the lesson.

A. Caraballo (1985) studied the following lesson presentations: 1) text only; 2) text plus visuals; and 3) text plus still and animated visuals. A total of 109 college seniors and graduate students participated. The lesson content taught computation of area of geometric shapes. No significant differences between the groups were reported. This study appeared to follow appropriate instructional design procedures: two pilot studies using only the first treatment were conducted to validate the materials and also to determine where additional lesson support was needed. Despite this, there are two factors which may have served to confound the results. First, again, an older population was used as subjects. Second, the instructional result of the animation appeared to be as an aid to conceptual understanding rather than presentation. Animation was used to only indirectly show the relationship between geometric shapes as an aid in computing area. Geometric shapes were moved on the screen to show their relationships. For example, two identical triangles were animated to demonstrate how they form a parallelogram. Generally, most college seniors and graduate students would know or remember these relationships with little prompting. For this reason, the addition of animation probably had nominal effect on overall achievement.

Reed (1985) conducted a series of four experiments investigating graphics conditions in the teaching of a variety of algebra word problems. The design of the four experiments followed an iterative process where results of the first experiment were used to improve the instructional delivery in the second experiment, and so on. Different groups of 30 undergraduates participated in each of the first three experiments and in each of the three conditions compared in experiment 4 (for a total of 180 subjects). Experiment 4, studied the final modified lesson across three conditions and across four word problem types (average-speed problems, tank problems, mixture problems). The experimental conditions for each word problem type depended on the results from experiments 1-3. Several hypotheses were tested, including effects of feedback and graphics. Results were mixed according to the word problem task. Student performance on the mixture problems did not depend on the availability of graphics, whereas graphics effects were found for tank problems, but only when paired with the additional strategy of requiring students to make estimations. These results suggest the inability of students who are novices in the content to accurately perceive differences in animated graphic presentations when only required to view the graphic presentation. More accurate perceptions were elicited when the graphic representation was coupled with an instructional strategy which required learners to attend more to the information contained in the graphic.

Rieber and Hannafin (1988) investigated computer animation as an orienting aid during instruction. This study differs from the previous studies in two important ways. First, the previous studies used an older population. College-aged students probably do not benefit from instruction which contains additional visual elaborations since they are able to form mental images without additional lesson support. The Rieber and Hannafin study investigated animation using 111 fourth, fifth, and sixth grade students — a sample from a population expected to benefit more from visual

elaborations than adults. The second major difference concerns the role played by animation in the lessons. The potential of animation to support lesson material in previous studies was limited in that motion and trajectory were not necessarily criterion aspects of the content to be learned. This study used animation on the basis of its appropriateness or congruency to the criterion tasks. The lesson content taught Newtonian physics by presenting a simplified account of Newton's laws of motion. Each lesson part was preceded by one of the following four types of orienting activities: 1) text only; 2) animation only; 3) text plus animation; and 4) no orienting activity (control). No significant differences were reported among the four treatments. They reported that the nonsignificant differences may have been due, at least in part, to the general ineffectiveness of orienting activities as an influence on learning (as suggested in other research such as Hannafin, Phillips, Rieber, & Garhart, 1987).

Rieber (in press) followed-up this research to investigate the effectiveness of animation when part of the primary presentation of relevant content. In this study, visual elaborations of the laws of motion content used in the Rieber and Hannafin (1988) study were embedded throughout the lesson. The placement of these embedded visual elaborations were determined by two pilot studies using an all-text version of the content. Student deficiencies in meeting the objectives tested in the posttest were traced back to the lesson presentation and then strengthened with the embedded visual elaborations in the main experiment. The main experiment studied the crossed effects of graphic (static, animated) and textual (text, no text) embedded lesson elaborations and practice (relevant, irrelevant) on factual and application learning of 192 elementary school students. Relevant practice consisted of asking traditional multiple-choice questions after each of the four lesson parts. No significant differences were found among the groups. Several explanations were suggested. First, the students apparently found the lesson content exceedingly demanding which may have served to confound the results. Second, a follow-up analysis of the time spent by student viewing lesson frames containing embedded visual elaborations suggested that students may not have adequately attended to the visuals.

Rieber, (1988) replicated the previous study with several modifications. First, the lesson difficulty in terms of factual and concept density was reduced. Second, the method used to display lesson information was changed in order to better cue students as to what to select and attend to in the lesson. In the Rieber (in press) study, an entire frame was presented to the student at a time with student able to trigger the next frame by pressing the space bar. In the Rieber (1988) study, each frame was broken down into textual and graphic "chunks". Rather than presenting an entire frame of information at a time, each student viewed only a portion of the frame at a time, pressing the space bar when ready to view the next portion or "chunk". This procedural change was most dramatic in the presentation of animated information. Students' attention was more easily directed to and less likely to be distracted away from the animated presentation. Practice was also studied in the form of traditional questioning techniques but also as dynamic interactions consisting of levels of a structured simulation. Results indicated the animated graphic group was superior to both the static graphic and no graphic groups. Also, students in the interactive dynamic practice group outperformed the no practice control group whereas the question practice group did not. An interesting interaction was found between the visual elaboration and practice factors. The animation effect was eliminated without any form of practice. Practice, of either type, seemed to direct students' attention to relevant details in the tutorial. Another interesting finding was animation's influence on incidental learning. The animation group saw a graphic example of Newton's second law. In one frame, graphics of a small ball and a large brick were given equally strong kicks. The acceleration experienced by the ball was dramatically greater than the brick. Although no formal attempt was made to teach this rule, this group seemed to learn this application of Newton's second law based solely on viewing this one frame.

Rieber, Boyce, and Assah (1988) replicated the Rieber (1988) study with 141 adult learners. The purpose of this study was to investigate whether the animation effects on young children would be replicated with adults. The same lesson content was used, but was extensively modified for the adult group. No differences were reported between the visual elaboration conditions on the performance measure. This is consistent with previous research using adult subjects. However, an analysis of subjects' response latency on the posttest indicated that subjects in the animated visual

condition took significantly less time to answer posttest questions than subjects in either of the other visual conditions. Thus, the animated visual presentations appeared to aid subjects in the reconstruction process during retrieval. Also, a moderate interaction between the visualization and the practice factors was noted. This interaction indicated the trend that the static graphic and no graphic groups were influenced more by practice than the animated graphics groups. This implies that subjects in the animated graphics group did not require the additional elaboration and rehearsal contained in the practice as much as subjects in the static graphics and no graphics groups.

A variety of other related research has been reported. Riding and Tite (1985) found that computer generated animated visuals effectively prompted nursery school subjects to generate original stories as compared to static visuals and a control condition. Many non-computer studies, involving primarily video, have been conducted over the past 25 years. Spangenberg (1973), for example, taught and tested procedural learning skills (the disassembly of a machine gun) with adults. He found motion sequences superior to stills but this effect was eliminated when the stills condition was revised and retested (in other words, the instructional design was improved). Blake (1977) used static and animated arrows in video instruction to cue subjects' attention to the movement of chess pieces. This study controlled for spatial aptitude of subjects and found that subjects of low spatial aptitude benefited from motion sequences whereas no effect was found for subjects with high spatial aptitude. Finally, Goldstein, Chance, Hoisington, and Buescher (1982) found that subjects' recognition memory was superior for dynamic video scenes as compared to static video scenes from selected excerpts of Hollywood movies. (See Chu & Schramm, 1979 for a further review of early motion studies in television research.)

Summary

Frequently, results from the King (1975) and Moore, Nawrocki, and Simutis (1979) studies are cited as conclusive evidence that animated instruction is ineffective. Clearly, these two studies hardly represent sufficient research data to support such a conclusion. Some of the reported research hints at contexts where animation has at least some empirical support with certain populations. Children's learning of certain science concepts when the difficulty level is matched with ability is one example. The effect of animation on incidental learning also warrants further study. Other research (e.g. A. Caraballo, 1985; Collins, Adams, & Pew, 1978) which studied animation as an interactive dynamic or as an aid to conceptual understanding, where differentiated effects of animation are difficult to distinguish, perhaps present more questions than they answer.

Conclusions and Prescriptions

Guidance in the application of computer animation in instruction is needed, especially as the technology continues to evolve and expand to include such things as three-dimensional animation (Zavotka, 1987). The following conclusions and prescriptions are not meant to represent the final word on instructional applications of animation, but as temporary assistance to practitioners. Additionally, it is hoped that these will act as a catalyst for more research and discussion.

Little research exists which has studied animation systematically apart from static visuals. One obvious conclusion from the several studies reviewed here is that the pool of available animated visual research is generally small. Additionally, several of the reported studies failed to systematically investigate the relative unique contribution of animation as compared to static visuals. That is, the unique instructional contribution of animated visuals is still largely unsubstantiated. Clearly more research is needed.

In general, animation has not proven to be an effective or reliable presentation strategy when considered or studied separately in controlled experiments; any effects, if real, are subtle. This is the issue of efficacy. Animation does not appear to be a powerful influencer on learning. Effects attributable to animation, if any, are perhaps dependant on other lesson components, such as lesson organization or practice. For example, the Rieber (1988) study indicated an interaction between animation and practice such that animation was only effective when moderate amounts of practice were also provided. Those who design lessons which follow poor instructional designs can expect little from additional special effects

(like animation) and instead should probably expect detrimental effects, like distraction.

The instructional intent of animation should be based on the instructional result desired. Perhaps this akin to beating the proverbial dead horse, but it should be clear by now that there are many ways in which animated visuals can be used. Haphazard integration of animation can lead to a variety of instructional outcomes, not all of which are positive. Designers should carefully consider their instructional intent and how closely it will influence the desired instructional result. The taxonomy of instructional applications of animation was offered as a guide in this process.

Animation should be incorporated only when its attributes are congruent to the learning task, otherwise, distraction effects may result. If the demands of the learning task involve the attributes of visualization, motion, and trajectory, such as many objectives in science education, then a supporting rationale exists for incorporating animation. If these attributes do not contribute to the learning task, then the learner may be distracted by their presence.

Evidence suggests that when learners are novices in the content area, they may not know how to attend to relevant cues or details provided by animation. Details provided in animation that experts see as obvious or clear may be completely overlooked by novices. That is, the learners may be unable to "read" animated visuals nor be able to integrate with verbal descriptions (cf. Rieber, 1988; White, 1984). This is especially important to note when instruction is designed by a content expert, as is frequently the case. Care should be taken to deliberately cue the learner to watch for the details in the animation which are most relevant (eg. changes in speed and/or direction).

Some aptitude by treatment interactions (ATI's) between learner maturation and spatial aptitude and animation suggest favoring the use of animation in certain cases. Although virtually no specific instructional animation research on this point is available (an exception includes Blake, 1977), several ATI recommendations can be extrapolated from general research. Research indicates that internal mental imagery is developmental in nature. Young children are less likely and less capable than adults to form internal mental images spontaneously. Additionally, individual differences exist in overall spatial ability. Therefore, when the attributes of the learning task are congruent to the attributes of animation, young children and other individuals who possess less spatial ability should particularly benefit from the use of these visuals.

More dramatic benefits of animation may lie in its contributions to CBI applications such as interactive dynamics. Many reported studies suggest that animation's greatest potential may lie in its use as an interactive dynamic. Unfortunately however, it may not be possible to adequately partial out animation's distinguishable role when used in this way. That is, interactive dynamics represent highly sophisticated and complex exchanges or "transactions" between the student and the instruction which cannot be broken down easily into its representative parts, which includes for example, animation. However, the fact that these instructional transactions would not be possible without animation attests to its utility in this area.

Instructional design and learning theory should drive the use of animated visuals, and not simply what the hardware is capable of doing. Technical abilities of hardware and programmers, in and of themselves, have no bearing on their potential instructional effectiveness. The fact that animation *is* an option does not mean that it ***should*** be an option. CBI designers are faced with a curious dilemma. They must resist incorporating special effects, like animation, when no rationale exists, yet must try to educe creative and innovative applications from the computer medium. Instructional design still represents the recommended process for identifying instructional problems and then designing, developing, and evaluating instructional solutions on the computer or with other emerging technologies, such as interactive video and hypermedia (Hannafin & Rieber, in press).

Closing

The general failure of animation to impact learning empirically contrasts the theoretical bases (in mental imagery and visualization) which support it. However, general procedural flaws in several of the animation studies, as well as a lack of generality of results, make interpretation inconclusive. If

animation is an effective instructional element, its influence is probably not as evident in the presence of well-designed and organized instruction. Its influence, like many other instructional aids, may be weakened in the presence of more powerful lesson elements (cf. Mayer, 1979). In addition, the effects of animation could be dependent on content and learning task variables.

Designers and consumers of educational software and emerging technologies should approach instructional uses of animation with caution. The few serious attempts to study the instructional attributes of animation have not adequately shown it to be effective. Although it is expected that the conditions under which animation is effective will eventually be empirically derived, adequate and accurate prescriptions, beyond the general ones already described, are not available. It could be that the discrepancy of expected results and empirical evidence demonstrates a failure on the part of researchers, rather than inappropriate applications on the part of designers and instructors. Research from related areas should serve to guide educators until more specific research data is available. For example, the potential for animation to distract learners should be noted. Related research has also indicated that developmental factors may be involved. Also, the way learners perceive animation could also have an effect on learning. Research suggests that there are optimal levels of motivation and arousal for many instructional components. When learners perceive components as requiring too little or too much effort, there is a tendency for them not to attend to the instruction appropriately (Salomon, 1983).

The research effort in static visuals represents perhaps a curious analogy to the current research in animation. Research prior to 1970 largely concluded that adjunct visuals either had no effect or negative effects on learning. Fortunately, research did not stop based on this conclusion. It took more time coupled with a systematic effort to finally describe the ***conditions*** under which static visuals could be used effectively to promote learning (Merrill & Bunderson, 1981) and it is only recently that this research base has started to be effectively applied to instructional computer graphics (Alesandrini, 1987). It is suggested that research into animated visuals will require a similar systematic process and effort to uncover unique conditions.

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Table 1

Summary of Empirical Research Studying the Instructional Effects of Animation

Study	Subjects #	Subjects Age	Content	Results Regarding Animation	Comments
Rigney & Lutz, 1975	40	Adult	Science: How a battery works	Higher recall for pictorial group	No control for static vs. animated visuals
King, 1975	45	Adult	Math: sine ratio	NSD	Learning task not sufficiently difficult
Collins, Adams, & Pew, 1978	18	Adult	Geography of South America	Interactive Map> Labeled Map> Unlabeled Map	Animation used as an interactive dynamic, not as an elaboration of lesson content
Moore, Nawrocki, & Simutis, 1979	90	Adult	Psychophysiology of audition	NSD	Confounding due to instructional design: review was automatically given to students after each lesson part if achievement less than 85% thus producing a ceiling effect
Caraballo, J., 1985	109	Adult	Physiology of human heart	NSD	No validation done to determine if additional visuals were needed
Caraballo, A., 1985	109	Adult	Computation of area of geometric shapes	NSD	Animation used as an aid to conceptual understanding, not as an elaboration of lesson content
Reed, 1985	180	Adult	Algebra word problems	Mixed according to word problem type	Lessons were iteratively improved over 4 experiments; Animation effective when replacing rather than supplementing verbal info
Rieber & Hannafin, (1988)	111	Children (elem.)	Newton's laws of motion	NSD	Animation studied in context of orienting activity; possible confounding due to lesson difficulty
Rieber, in press	192	Children (elem.)	Newton's laws of motion	NSD	Possible confounding due to lesson difficulty
Rieber, 1988	119	Children (elem.)	Newton's laws of motion	Animation>Static= None; Interaction between visuals & practice	Animated visuals contribution distinguishable from static visuals; animation most effective when practice support was moderate; moderate animation effect in promoting incidental

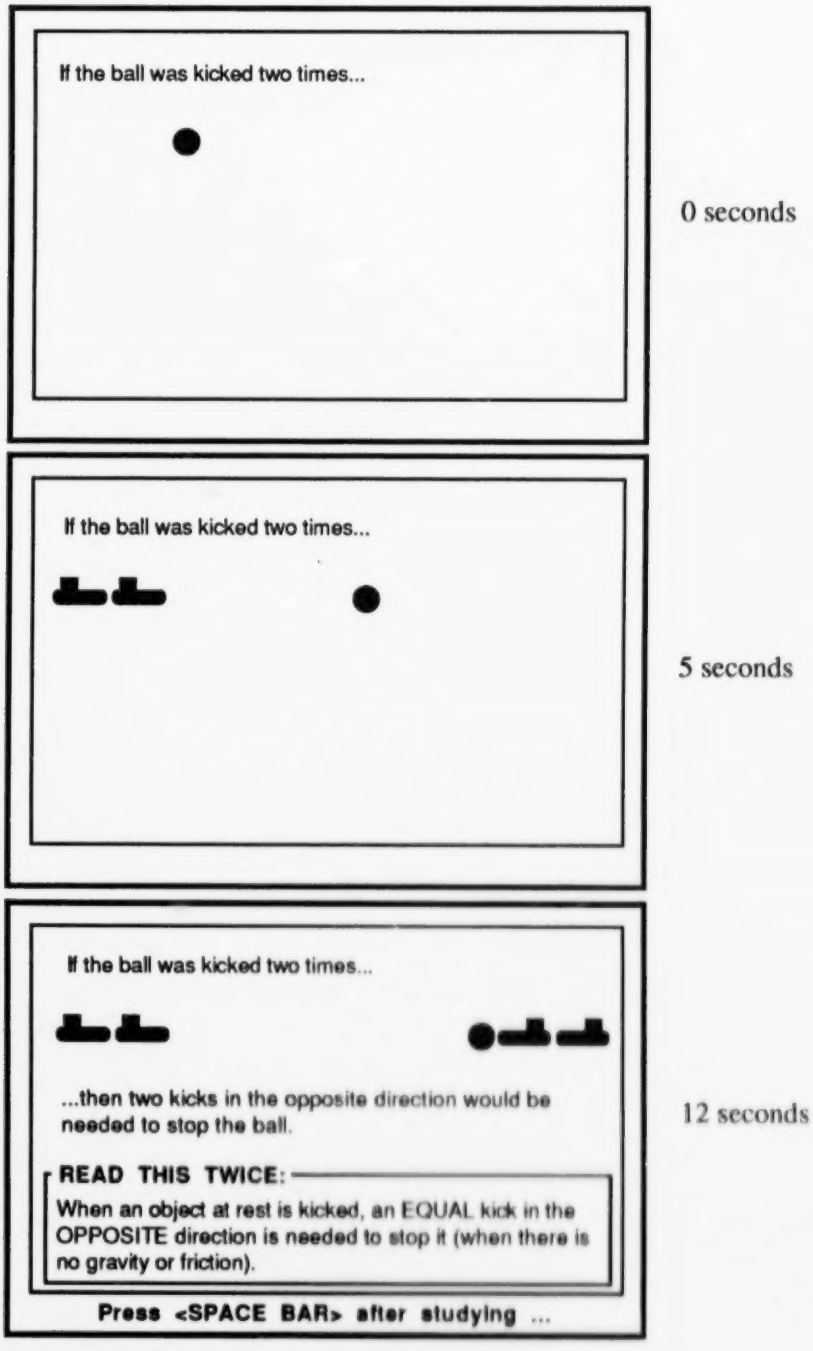
If the ball was kicked two times...
0 seconds
If the ball was kicked two times...
5 seconds
If the ball was kicked two times...
...then two kicks in the opposite direction would be needed to stop the ball.
12 seconds
READ THIS TWICE:
When an object at rest is kicked, an EQUAL kick in the OPPOSITE direction is needed to stop it (when there is no gravity or friction).
Press <SPACE BAR> after studying ...

Figure 1. An example of using animation as an adjunct presentation strategy in science.

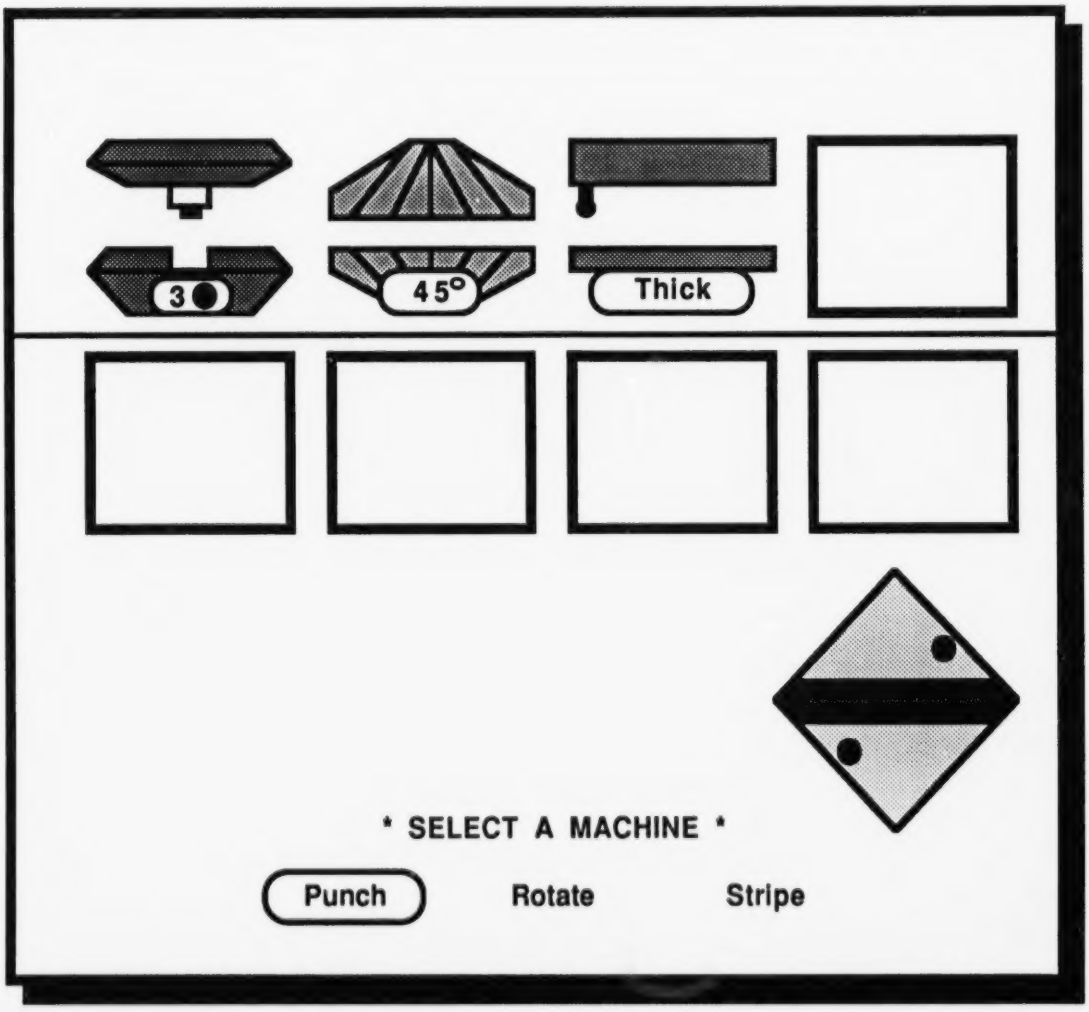

Figure 2. An example of using animation as an aid to conceptual understanding: the student constructs a factory then watches the transformation of the "raw material".

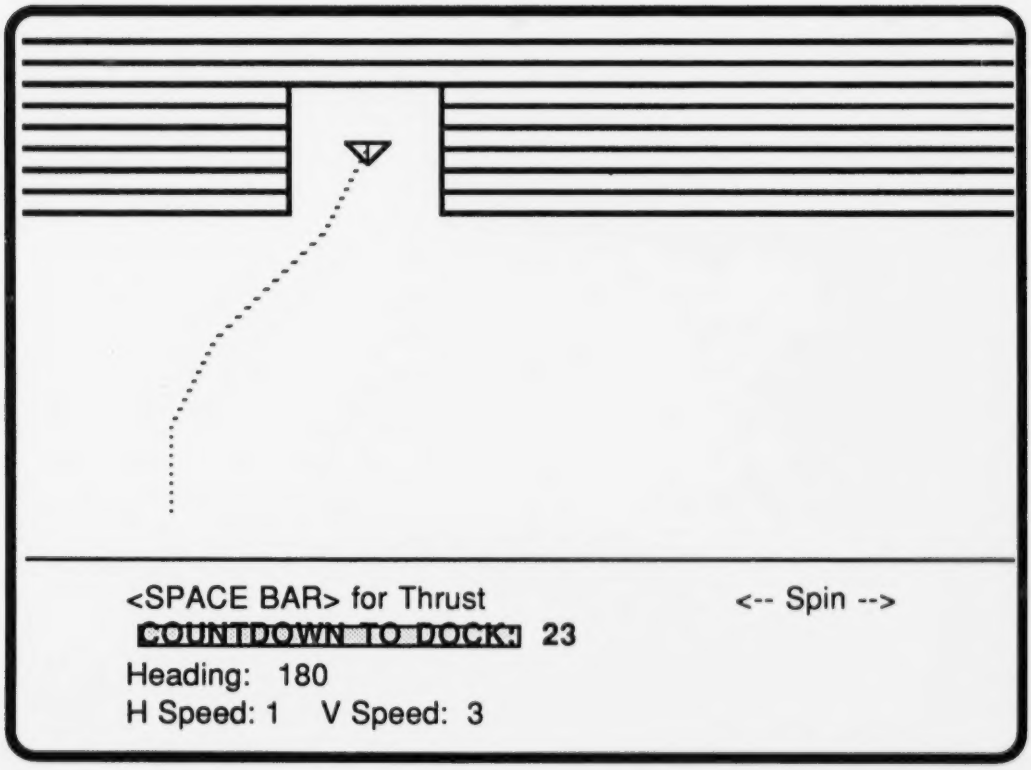

Figure 3. An example of using animation in an interactive dynamic: the student is in control of a free-floating "starship" attempting to dock with the "parent" ship.